

finding that, when operated at similar power levels, both CDMA and GSM phones can create audible interference within a nearly equal range of detectability.

The Qualcomm tests measured CDMA mobile units at a maximum operating level of 200 milliwatts peak power at both 800 MHz (cellular) and 1900 MHz (PCS) frequencies.² The U.S. standard for CDMA cellular phones, TIA/EIA IS-95(A), provides for three classes of mobile units: a 1.0 watt maximum output power (i.e., 1000 milliwatts) for Class III, a 2.5 watt maximum output power for Class II, and a 6.3 watt maximum output power for Class I. The U.S. standard for CDMA PCS mobile units, ANSI J-STD-008, provides for five different classes of mobile units: 130 milliwatt maximum output power (Class V), 250 milliwatt maximum output power (Class IV), 500 milliwatt maximum output power (Class III), 1 watt (1000 milliwatt) maximum output power (Class II), and 2 watts (2000 milliwatt) maximum output power (Class I). Regardless of the U.S. CDMA standard selected, there is no CDMA mobile unit designed to operate at the 200 milliwatt maximum output power utilized by Qualcomm for its test.

Just as Qualcomm used a non-standard power level to measure its CDMA phones, throughout most of its July 1995 Report, Qualcomm selected a 2 Watt power level that does not

² July 1995 Report at 2.

exist in the United States to use as its measurement of GSM phones.³ Qualcomm states that it performed "one set of tests at 800 MHz with a simulated a GSM signal at a normal GSM phone operating level (2W peak, 217 Hz burst rate, 1/8 duty cycle)"⁴ and a second set of tests at 1900 MHz "at a GSM power level of 1 watt."⁵ There is no U.S. standard (or use) for GSM devices operating in the 800 MHz range at 2 W or any other power level. Qualcomm, however, correctly used the U.S. GSM standard for its tests of the output of GSM 1900 mobile units at 1 watt maximum output level.⁶

To make meaningful comparisons between similar CDMA and GSM phones, *i.e.*, the PCS hand-held mobile units that actually will be used in the United States, the results of the tests described in the July 1995 Report first must be adjusted.

³ The one exception is the bottom of page 4, which is the only part of the July 1995 Report where Qualcomm provides data with respect to a GSM phone operating at 1 Watt, which is the U.S. standard for GSM phones operating in the 1900 MHz (PCS) frequency band.

⁴ July 1995 Report at 2.

⁵ *Id.*

⁶ The only data reported at U.S. PCS frequencies and power levels is in a single chart and paragraph on page 4 of the July 1995 Report.

For the sake of a more relevant comparison, Qualcomm could have selected a GSM 1900 mobile station (Class II) operating at the U.S. standard of 250 milliwatts maximum output power. See ANSI J-STD-007.

The first adjustment is to compare CDMA and GSM outputs at power levels and operating modes defined by U.S. standards.⁷ The chart on page 4 of the July 1995 Report, *Range of Audible Interference (1900 MHz)*, even though it measures a non-standard 200 milliwatts CDMA phone, indicates that the CDMA phone in the U.S. standard variable rate vocoder mode generates audible interference for a range of approximately 0.1 meter (i.e., approximately four inches) to approximately 1.3 meters (i.e., slightly more than four feet).⁸

Another important adjustment involves system power control. In the Conclusion of its July 1995 Report, Qualcomm states, "In normal operation, where all CDMA phones are subject to system power control, transmit power levels vary, averaging 10 to 20 [milliwatts] of peak output power. Measurements made at 20 [milliwatts] indicate the radiating antenna must be within 2 to 13 cm (1 to 5 inches) for audible interference to be detected in hearing aids."⁹ But then Qualcomm continues, "[c]onversely, a GSM TDMA portable

⁷ Consequently, the test data shown on pages 1-3, the top of page 4, page 5, and the top of page 6 do not pertain to the U.S. application of GSM and CDMA technologies.

⁸ There is no U.S. standard for a locked full rate vocoder.

⁹ July 1995 Report at 6.

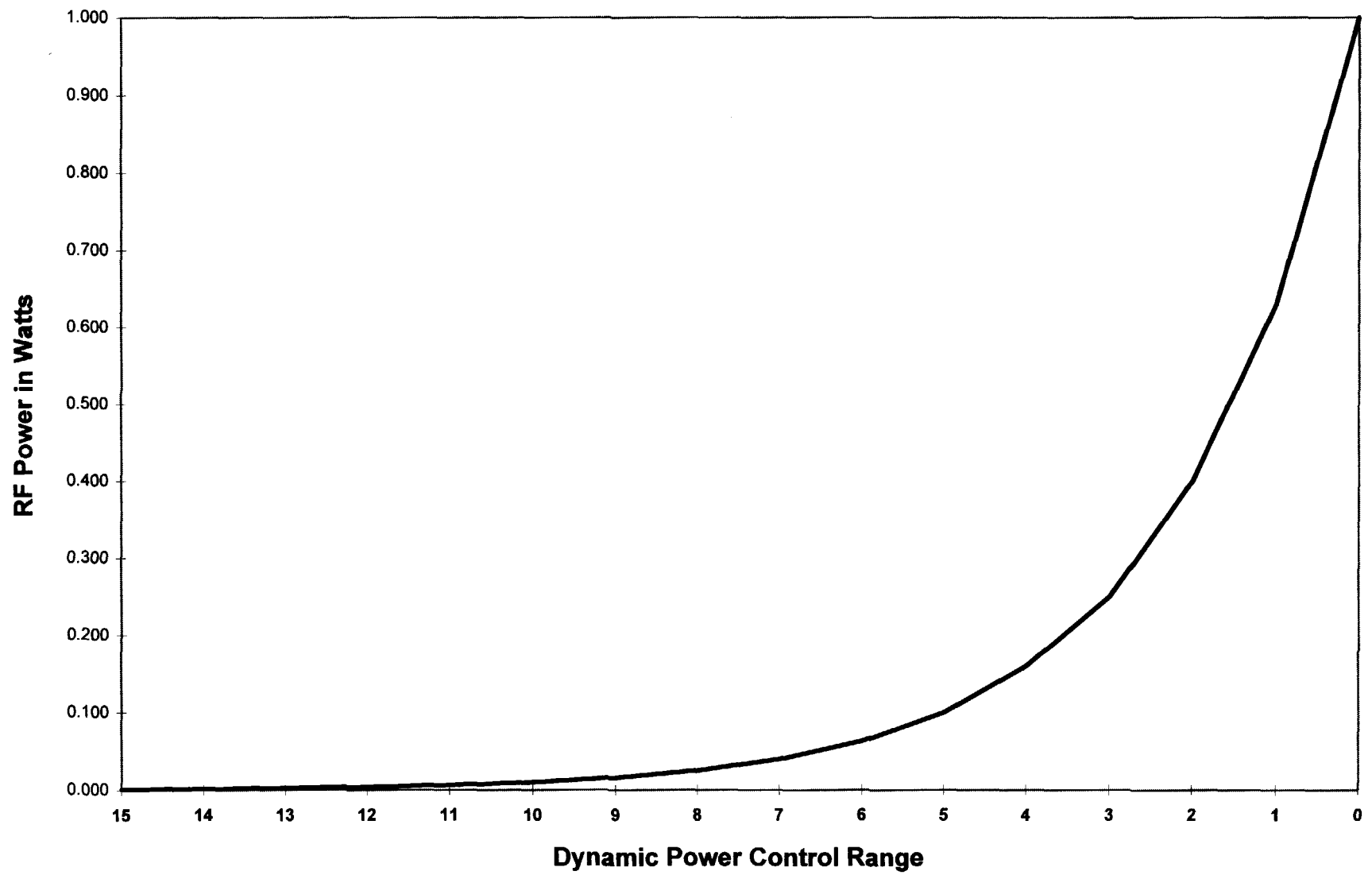
in normal operation transmits at a nominal peak power level of 2 watts (1 watt at 1900 MHz). Tests showed that a GSM portable located within a distance of 1 to 3.5 meters from a hearing aid would cause audible interference."¹⁰ Qualcomm fails to mention that GSM phones also operate under system power control with an operating range of 1 milliwatt to 1.0 watt. Unlike their reference to CDMA phones, Qualcomm provides no data for GSM phones operating under system power control. As the attached chart demonstrates, under the power levels established by the U.S. standard for PCS 1900 phones, power levels below 20 milliwatts also predominate.

When these adjustments are made, as Qualcomm has demonstrated in earlier studies, both CDMA and GSM phones at similar power levels can create audible interference within a range of detectability that is nearly equal.¹¹

¹⁰ July 1995 Report at 7.

¹¹ For example, at identical 200 milliwatt power levels, a hearing impaired listener with a Phonak PE 845 hearing aid could detect interference from a CDMA phone at 25 cm (9.8 inches), while the same listener could detect interference from a GSM phone at 30 cm (11.8 inches). In this same test, interference was judged as becoming "annoying" at 8 cm (3.1 inches) for the CDMA phone, compared to 14 cm (5.5 inches) for the GSM phone.

Handheld Class 1 PCS1900 GSM Power Levels



APPENDIX B

**PROTOCOL FOR THE STUDY OF
HEARING AID INTERACTION WITH
WIRELESS PHONES**

Version 2.0

**CENTER FOR THE STUDY OF WIRELESS
ELECTROMAGNETIC COMPATIBILITY**

**SCHOOL OF INDUSTRIAL ENGINEERING
UNIVERSITY OF OKLAHOMA**

July 25, 1995

INTRODUCTION

This protocol has been developed in support of a study, on the interaction between various types of wireless telephones and hearing aids to be conducted at the University of Oklahoma. The overall purpose of the study is to objectively and subjectively, evaluate the interference between wireless phone technology and hearing aids. The Phase I objectives of the study are to:

1. define the test protocol for physical measurement of the interference generated in hearing aids by wireless phone signals of varying types. The resulting protocol shall produce repeatable results and include parameters such as field strength, threshold distance of interference, and intensity and frequency of the resulting audio interference output;
2. define a standard methodology for measuring the immunity of hearing aids, including standards for acceptable "noise floors"; and
3. define the test protocol for subjective measurement of the extent of the interference generated in hearing aids by wireless phone signals of varying types. The protocol shall include the use of both hearing-impaired and unimpaired individuals.

Background

This protocol is based on input from the references listed at the end of this document and from members of the Hearing Aid Wireless Phone Interaction Study Design Group. Much of the protocol is based on a study conducted by the National Acoustic Laboratories, a division of the Australian Hearing Services (Le Strange, Byrne, Joyner, and Symons, 1995).

European and Australian clinical and laboratory studies have demonstrated that audible interference ("buzzing") can be produced in hearing aids by hand-held wireless phones operated in close proximal, (a few centimeters to several meters). This effect has been demonstrated in the US but little has been published in terms of research results. This protocol encompasses both physical measurement of hearing aid interference (objective testing) and how this interference is perceived by hearing aid users (subjective testing). The model outlined by Bowen (1995) identifies one possible breakpoint that connects the objective and subjective testing. Physical testing involves the RF source, RF path, and the hearing aid (objective). Output from the hearing aid is acoustically coupled to the user who develops a perception of the interference signal (subjective). Objective and subjective tests can be independent.

PROTOCOL FOR THE STUDY OF HEARING AID

INTERACTION WITH WIRELESS PHONES

CURRENT RESEARCH

Currently reported studies in Europe and Australia have examined the interference generated by GSM phones, the predominant wireless phone technology outside of the US. GSM uses a Time Division Multiple Access (TDMA) signal structure as do most digital wireless phones in the US. The TDMA principle results in the carrier being pulsed in a fashion that allows audio frequency devices (hearing aids, portable stereos, etc.) to demodulate the radio frequency (RF) envelope and produce a constant, distinctive buzzing sound. According to reports, these TDMA signals

interfere with hearing aids from as far as 30 meters depending on the hearing aid model. At a range of 3 to 5 meters, hearing aid users may experience a 200 Hz humming noise overpowering all other signals. This is a particular problem for hearing aid wearers who wish to use wireless phones. The degree of interference immunity varies widely by hearing aid type with the in-the-ear (ITE) devices typically having higher immunity. The level of interference is also affected by the relative orientation of the hearing aid and the phone.

Physical Measurements

Quantification of the sensitivity of a particular hearing aid (HA) to wireless phone interference is the first step in the ultimate development of immunity standards. Physical testing of HA immunity requires an RF signal source for generation and propagation of the appropriate cell phone signal, a controlled RF environment, a means for mounting and orienting the HA, and instrumentation for measuring the level of the audio interference output.

RF Test Signal

Previous researchers have employed various RF test signals to represent the GSM RF signal, including:

1. 900 MHz pulse modulated carrier with a modulation frequency of 217 MHz duty cycle of 1:8 and 100% modulation (EHIMA, 1993; Joyner et al., 1993; National Telecom Agency of Denmark, 1994), and
2. a 900 MHz carrier, 80% modulated by a 1000 MHz sine wave (IEC, 1994; Le Strange et al., 1995).

No reports have been located in which the physical measurement testing was conducted using actual wireless phones. Some subjective testing has been reported with actual phones (Le Strange et al., 1995).

This study will use actual wireless phones. Some models will be "hot wired " or programmed in a continuous transmission mode. Other models will communicate with an HP 8920A RF Communications Test Set functioning as a base station simulator. This approach provides the greatest realism in terms of actual signal structure including the format for control and voice traffic (e.g., paging, power control, channel changes). This approach requires an accurate means of measuring RF field intensities generated by the phones at various distances.

RF Environment

Previous researchers have employed or compared various RF test environments, including:

1. a radio frequency anechoic room (EHIMA, 1993; IEC, 1994; Le Strange et al., 1995),
2. "stripline" consisting of a ground plane, stripline conductor, and 50 ohm resistive matching network (EHIMA, 1993), and
3. a waveguide (Joyner et al., 1993; Le Strange et al., 1995).

RF field intensities have either been fixed at 10 V/m or varied up to 200 V/m.

None of the three previously used RF test environments have been selected for this study. Options 2 and 3 are precluded by the fact that actual phones along with their self-contained antennae will be used as the signal source. Testing will be conducted at

the AT&T Open Area Test Site (OATS) In Oklahoma City. A radio frequency anechoic room (Option 1) is not currently available at this facility. Therefore, testing will be conducted within the shielded room at the OATS facility. The possibility of using a GSM cell will also be explored.

Mounting and Orienting the Hearing Aid

The hearing aid must be positioned in the RF test field away from objects that could distort the field and in such a way that it can be manipulated for maximum interference. Previous protocols have used the following:

1. place HA in chamber in "normal use" position, rotate (clockwise) in 90° steps in the horizontal plane, measure interference at maximum SPL (EHIMA, 1993; IEC, 1994; National Telecom Agency of Denmark, 1994),
2. use both horizontal and vertical polarization of the RF field (EHIMA, 1993),
3. gimbal style mounting device for positioning HA in the waveguide about three axes, rotate for maximum pickup (Le Strange et al., 1995), and
4. mount within the Kemar head (no reference found at present).

Discussions of the Study Design Group led to the conclusion that the Kemar head (Option 4) was not an effective means of mounting the hearing aids since it did not provide a good RF analog of the human head. Option 3 is unique to the waveguide approach which is not being used in this study. Options 1 and 2 will be combined through the user of a non-RF distorting mounting device for alignment of the HA and a device for positioning of the phone.

Measuring Hearing Aid Output

The output of the HA must be measured without introducing instrumentation that could distort the RF field. This has typically been accomplished by using small diameter (2 mm) plastic tubing with a length between 50 mm and 500 mm to distance the HA and the acoustic monitor (IEC, 1994). Specific examples include:

1. ear simulator (IEC 711) to audio test station, amplifier, and DAT recorder via 500 mm tubing (EHIMA, 1993; National Telecom Agency of Denmark, 1994), and
- 2). standard 2 cc acoustic coupler to measuring microphone (B&K4155) and measuring amplifier (B&K 2636) via 500 mm length of 2 mm Tygon© tubing (Le Strange et al., 1995)

Option 2 will be used in this study based on available models of audio monitoring equipment.

Subjective (Psycho-acoustic) Measurements

Subjective evaluation of wireless phone interference is important since the detectability and annoyance of the interference depend on the individual hearing acuity of each HA user. Detectability and annoyance levels should be determined for hearing-impaired people with hearing losses appropriate to each type of HA. Persons with normal hearing should also be included to represent worst case situations of detectability and annoyance. Detectability can be determined through the application of standard psychophysical techniques such as the method of limits or method of constant stimuli. The degree of annoyance is typically ascertained through the use of subjective scaling techniques.

Interference Source

Subjects may be presented with either actual or recorded interference signals. Specific examples include:

1. recorded interference signal together with pinknoise, "partysounds", or connected speech (EHIMA, 1993; National Telecom Agency of Denmark, 1994), and
2. actual phone with call placed to pre-recorded message (Le Strange et al., 1995). A variation of Option 2 can be achieved through the use of the base station simulator and the cell phone loopback (talkback) mode or audio transmission from the base station.

Detectability

Interference can be recorded on DAT or generated directly with actual phones for evaluation of detectability. Any of the following schemes can be used:

1. samples of various levels of recorded interference can be replayed in random sequence at random intensity levels while subjects are asked to respond as to the presence or absence of interference,
2. subjects wearing hearing aids are tested by moving an actual phone across a number of test sites from far (4 m) to near and back while the subject indicates the presence or absence of a "buzz" (Le Strange et al., 1995), and
3. subjects can listen through tubing to actual hearing aid output with the HA at various locations (e.g., close to phone as in listening to a call, one meter, and up to several meters). The acoustic level of interference is classified as: "not perceptible", "just perceptible", "moderately perceptible", and "annoyingly perceptible" (Le Strange et al., 1995).

Annoyance/Usability

The interference signal is presented at random intensity levels and/or varying distances while subjects are asked to respond with the corresponding level of annoyance. Examples of the scales used include:

1. "not annoying", "slightly annoying", "annoying", and "very annoying" (EHIMA, 1993), and
2. "usable", "sometimes usable", and "unusable" (Le Strange et al., 1995).

Tests for Detectability, and Annoyance will be combined using a hybrid mixture of Options 2 and 3 above under detectability. This provides a more authentic test for the extent of the problem as determined by subjects listening to the actual interference.

Experimental Variables

The experimental variables in the study consist of the independent variables which are manipulated, dependent variables which are measured, and control variables. The control variables are defined by the test environment ("test bed"), test apparatus and experimental procedure. The dependent variables include the physical measurements and characteristics of the interference levels and immunity "scores", and the subjective responses for detectability and annoyance. The independent variables represent those factors which are tested to determine their influence on the dependent measures (both objective and subjective). Potential factors in this study are presented in outline form in the following section labeled Experimental Design.

EXPERIMENTAL DESIGN

FACTORS AND LEVELS

Hearing Aids

Hearing aid types

Behind the ear (BTE)

In the ear (ITE)

In the canal (ITC)

Completely in canal (CIC)

(ITE, ITC and CIC comprise 80% of market)

New devices vs. current patients

Specific manufacturers, models, units/model (too many?)

Phones

Phone technology (in priority order)

1. TDMA (D-AMPS) @ 800 MHz (IS-54) and 1900 MHz (IS-136)

2. CDMA @ 800 MHz (IS-95) and 1900 MHz (J008)

3. PCS @ 1900 MHz (J007)

4. GSM @ 900 MHz

5. GSM @ 1900 MHz

Participating manufacturers

Test Procedure Variables

Distance between phone/simulator and HA

Side of head

Ipsilateral (same side) vs. contralateral (opposite side) use
(important because of Class I vs. Class II standards)

Phone use by others vs. phone use by HA wearer

Relative orientation

Antenna position/field polarization

Angle of coupling (HA orientation)

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Center for the Study of Wireless Electromagnetic Compatibility

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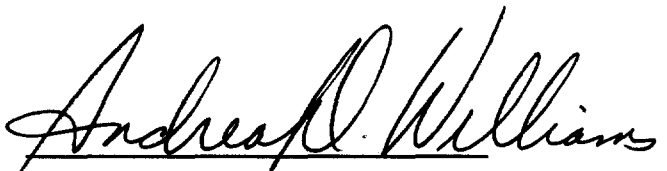
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CERTIFICATE OF SERVICE

I, Andrea D. Williams, hereby certify that on this 1st day of August, 1995, copies of the foregoing Reply Comments of the Cellular Telecommunications Industry Association were served by hand delivery upon the following parties:

Mr. William Caton
Secretary
Federal Communications Commission
1919 M Street, N.W., Room 222
Washington, D.C. 20554

International Transcript Service
1919 M Street, N.W., Room 246
Washington, D.C. 20554


Andrea D. Williams

CERTIFICATE OF SERVICE

I, Andrea D. Williams, hereby certify that on this 1st day of August, 1995, copies of the foregoing Reply Comments of the Cellular Telecommunications Industry Association were served by first class mail upon the following parties:

Mr. Gary M. Epstein
Ms. Teresa D. Baer
Latham & Watkins
1001 Pennsylvania Avenue, N.W.
Washington, D.C. 20004
Counsel for GSM MOU Association

Mr. Jonathan D. Blake
Mr. Kurt A. Wimmer
Ms. Laura F. Quinter
Covington & Burling
1201 Pennsylvania Avenue, N.W.
Post Office Box 7566
Washington, D.C. 20044
Counsel for American Personal Communications

Mr. Frederick H. Graefe
Mr. Michael Ruger
Counsel for HEAR-IT NOW
Baker & Hostetler
1050 Connecticut Avenue, N.W.
Washington Square Suite 1100
Washington, D.C. 20036-5304

Mr. Carole M. Rogin
Hearing Industries Association
515 King Street
Suite 4420
Alexandria, VA 22314

Ms. Anne-Marie Liss
Liss Communications Research
Post Office Box 16307
Arlington, VA 22215-1507

Mr. Kevin J. Kelley
QUALCOMM Incorporated
1233 20th Street, N.W.
Suite 202
Washington, D.C. 20036

Mr. E. Van Cullens
Siemens Stromberg-Carlson
900 Broken Sound Parkway
Boca Raton, FL 33487

Mr. Stephen L. Goodman
Halprin, Temple & Goodman
1100 New York Avenue, N.W.
Suite 650, East Tower
Washington, D.C. 20005
Counsel for Northern Telecom Inc.

Mr. David C. Jatlow
Young & Jatlow
2300 N Street, N.W.
Suite 600
Washington, D.C. 20037
Counsel for Ericsson

Mr. Eric Schimmel
Mr. Barry Kratz
Telecommunications Industry Association
2500 Wilson Boulevard
Suite 300
Arlington, VA 22201-3836

Mr. Tom A. Lippo
Fact Law Group
412 1st Street, S.E.
Suite One -- Lobby Level
Washington, D.C. 20003
Counsel for Nokia Mobile Phones, Inc.

Mr. James P. Tuthill
Ms. Betsy Stover Granger
Pacific Bell Mobile Services
4420 Rosewood Drive
4th Floor, Building 2
Pleasanton, CA 94588

Mr. James L. Wurtz
Ms. Margaret E. Garber
Pacific Bell Mobile Services
1275 Pennsylvania Avenue, N.W.
Washington, D.C. 20004

Mr. Mark J. Golden
Personal Communications Industry Association
1019 19th Street, N.W.
Suite 1100
Washington, D.C. 20036

Mr. R. Michael Senkowski
Mr. Jeff S. Linder
Mr. Eric W. DeSilva
Wiley, Rein & Fielding
1776 K Street, N.W.
Washington, D.C. 20006
Counsel for Personal Communications
Industry Association

Mr. Kenneth L. Judd
Southwestern Bell Mobile Services, Inc.
17330 Preston Road
Suite 100A
Dallas, TX 75252

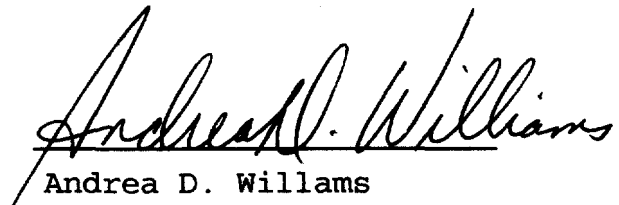
Mr. William B. Barfield
Mr. Jim O. Llewellyn
BellSouth Corporation
1155 Peachtree Street, N.E.
Suite 1800
Atlanta, GA 30309-2641

Mr. Henry Scott Fox
BellSouth Personal Communications, Inc.
3353 Peachtree Road, N.E.
Suite 300
Atlanta, GA 30326

Mr. Charles P. Featherstun
Mr. David G. Richards
BellSouth Corporation
1133 21st Street, N.W.
Washington, D.C. 20036

Mr. Andrew L. Tollin
Wilkinson Barker Knauer & Quinn
1735 New york Avenue, N.W.
Suite 600
Washington, D.C. 20006
Counsel for Bell South Corporation

Ms. Mary McDermott
Ms. Linda Kent
Mr. Charles D. Cosson
Ms. Kathleen M. Woods
United States Telephone Association
1401 H Street, N.W.
Suite 600
Washington, D.C. 20005-2136


Andrea D. Williams